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The r-process nucleosynthesis and related nuclear challenges

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The r-process nucleosynthesis and related nuclear challenges

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The rapid neutron-capture process, or r-process, is known to be of fundamental importance for explaining the origin of approximately half of the A > 60 stable nuclei observed in nature. In recent years nuclear astrophysicists have developed more and more sophisticated r-process models, eagerly trying to add new astrophysical or nuclear physics ingredients to explain the solar system composition in a satisfactory way. Recently, special attention has been paid to neutron star (NS) mergers following the confirmation by hydrodynamic simulations that a non- negligible amount of matter can be ejected and by nucleosynthesis calculations combined with the predicted astrophysical event rate that such events can account for the majority of r-material in our Galaxy
We show here that the combined contribution of both the dynamical (prompt) ejecta expelled during binary NS or NS-black hole (BH) mergers and the neutrino and viscously driven outflows generated during the post-merger remnant evolution of relic BH-torus systems can lead to the production of r-process elements from mass number A >~ 90 up to thorium and uranium. The corresponding abundance distribution is found to reproduce the solar distribution extremely well and can also account for the elemental distributions observed in low-metallicity stars. However, major uncertainties still affect our understanding of the composition of the matter ejected. These concern (i) the β-interactions of electron neutrinos and electron antineutrinos with free neutrons and protons, as well as their inverse reactions, which may affect the neutron-richness of the matter at the early phase of the ejection, and (ii) the nuclear physics of exotic neutron-rich nuclei, including nuclear structure as well as nuclear interaction properties, which impact the calculated abundance distribution resulting from the r-process nucleosynthesis. Both aspects will be critically discussed in the light of recent hydrodynamical simulations of NS mergers and microscopic calculations of nuclear decay and reaction probabilities.

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